07/11/95 10:51 ☎202 404 7475 AFOSR/NL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
7/31/95

3. REPORT TYPE AND DATES COVERED
Final Technical 1 June '94-31 May '95

4. TITLE AND SUBTITLE
Role of Persistence Cues in Disorientation/ Motion Sickness

5. FUNDING NUMBERS
F49620-94-1-0122
61102F
2313/CS

6. AUTHOR(S)
R. M. Stern, H.W. Leibowitz, W. J. Ray

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The Pennsylvania State University
110 Technology Center Building
University Park, PA 16802-7000

8. PERFORMING ORGANIZATION REPORT NUMBER
AFOSR-TR-95
0499

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NL
110 Duncan Avenue Suite 8115
Bolling AFB DC 20332-0001
Lt Col Daniel L. Collins

11. SUPPLEMENTARY NOTES

DTIC
SELECTE
AUG 30 1995
S D
F

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified/Unlimited

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The primary objective of the three studies completed was to determine whether motion sickness susceptibility was related to different measures of visual persistence. In these studies, motion sickness susceptibility was determined by exposing the subjects to a rotating optokinetic drum while the electrogastrogram and subjective indices of motion sickness were recorded concurrently. Subjects were tested for persistence of visual cues using one or more of the following procedures: a walking task, a computer simulation task, a temporal measures of vection, and three measures of spatial abilities. In Experiment 1, 50 subjects were tested; in Experiment II, 24; and in Experiment III, 45 were studied. Mixed results were obtained in the three experiments, but in general, those subjects who showed greater persistence, reported more severe symptoms of motion sickness. In addition, those subjects who did poorly on a water level test of spatial abilities, reported greater symptoms of motion sickness. We continue to believe that perceptual/cognitive style is germane to the issue of individual differences in responding to rapidly changing visual environments.

14. SUBJECT TERMS
Persistences, Disorientation, Motion Sickness, Perceptual Style, Electrogastrogram.

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

DTIC QUALITY INSPECTED 5

1995

GRANT NO. F49620-94-1-0122

ROLE OF PERSISTENCE CUES IN DISORIENTATION/MOTION SICKNESS

Robert M. Stern, Ph.D.
Herschel W. Leibowitz, Ph.D.
and
William J. Ray, Ph.D.
Department of Psychology
Penn State University
University Park, PA 16802

July 31, 1995

Final Report for Period 1 January 1994-31 May 1995

Accesion For	
NTIS CRA&I	☑
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

Prepared for

AFOSR
110 Duncan Avenue Suite B115
Bolling AFB DC 20332-0001

The overall purpose of this study was to investigate the relationship of the persistence of visual cues to motion sickness and disorientation.

Visual persistence. The effects of visual stimulation persist after the cessation of the light stimulus. For tasks such as the recognition of letters and words, this duration is of the order of a fraction of a second. However, for spatial orientation cues, duration of persistence is orders of magnitude longer. Consider for example the phenomenon of autokinesis in which a small light, viewed in an otherwise dark environment, appears to move erratically. The basic cause of this phenomenon is the lack of structure in the visual field. It is significant, however, that the illusory movement does not commence until some time, about 8 seconds, after the structure in the visual field has been removed.

Persistence of spatial orientation cues has been considered only recently in the literature. Thomson (1983) measured errors in perceived distance by asking subjects to walk with closed eyes to previously viewed targets that had been placed at distances ranging from 3 to 21 m. He concluded that observers internalize information about space and that this information is available for about 8 seconds. Data from several other studies can be interpreted in terms of the concept of cue persistence (e.g., Austin, Singer & Day, 1969; Matin & Li, 1992). Tyrrell, Rudolph, Eggers, and Leibowitz (1993) have demonstrated that the ability to locomote while blindfolded within the confines of a previously viewed pair of parallel lines on the floor decays exponentially with the delay between observation of the lines and the initiation of locomotion. Similarly, they have demonstrated that the ability to remember the location of a point of light in an otherwise dark chamber also exhibits an exponential decay as a function of delay.

Relationship between persistence and spatial disorientation/motion sickness. While the persistence of spatial orientation cues has adaptive value in preserving space constancy during eye movements, it would hinder the acquisition of new sensory-motor patterns. At this point in time, we know that persistence can be observed in a variety of situations (see Tyrrell et al., 1993 for a comprehensive listing), that it affects both sensory and motor responses, that it decays exponentially with a half-life of 10 seconds or more, and that intersubject variability is the rule. We hypothesized that this delay would increase susceptibility to motion sickness and spatial disorientation.

GENERAL METHODOLOGY

Motion Sickness. The primary objective of the three studies completed was to determine whether motion sickness susceptibility was related to different measures of persistence. In these studies, motion sickness susceptibility was determined by exposing the subjects to a rotating optokinetic drum while the electrogastrogram (EGG) and subjective indices of motion sickness were recorded concurrently. In numerous studies (e.g., Stern, Hu, Anderson, Leibowitz & Koch, 1990) we have demonstrated that changes in the frequency of gastric myoelectric activity, as measured with the EGG, is a sensitive, noninvasive, physiological marker of impending motion sickness. We quantify the EGG change of interest by doing a spectral analysis and determining the power at 4-9 cpm. This measure correlates very highly with subjective reports of motion sickness (Stern, Koch & Vasey, 1990).

Persistence of cues. Subjects were tested for susceptibility to motion sickness, as described above, and also tested for persistence of visual cues using one or more of the following procedures:

1) Walking Task-- Subjects were permitted to view a corridor for 10 seconds, on the floor of which there were two parallel lines. While blindfolded, the subjects walked as far as possible within the confines of the parallel lines. The time that separated the 10 second exposure to the corridor from the initiation of walking, the occlusion time, varied from 2 to 90 seconds.

2) Computer Simulation Task-- Subjects were permitted to view a computer screen which contained two parallel lines with an X between them at one end for 10 seconds. Following the same occlusion times as were used in the walking task, while blindfolded, the subjects used a mouse to move the X as far as they could within the confines of the parallel lines.

3) Temporal measures of vection (the illusion that the interior of the drum appears stationary while the subject feels her/himself to be rotating in the opposite direction) were obtained in the rotating drum when motion sickness susceptibility was tested.

4) Spatial Tasks-- Subjects completed a paper and pencil mental rotation task and a water level task. They also completed the rod and frame test.

EXPERIMENT 1

Method

Subjects. Subjects were 50 Penn State students, 17 males and 33 females. The procedure for this and the following two experiments was approved by the Penn State IRB. All subjects gave written informed consent.

Apparatus. Subjects were exposed to a rotating optokinetic drum in order to stimulate motion sickness. The drum consisted of a cylinder 91.5 cm in height and 76 cm in diameter. The interior was covered with alternating 3.8 cm (5.7 degrees) black and 6.2 cm (9.3 degrees) white vertical stripes. Subjects were seated inside the drum with their heads positioned in the center of the drum and aligned with the vertical axis. A miniature television camera was placed below the subject in order to monitor the subject's face and eyes. Verbal contact was maintained through an intercom system. The drum was rotated clockwise about its vertical axis at ten rotations per minute. Subjects could request termination of rotation at any time if they became too uncomfortable.

Symptom reports of motion sickness were collected using a modified version of the Pensacola Diagnostic Index (Graybiel, Wood, Miller & Cramer, 1968) which scores symptoms of dizziness, headache, warmth, sweating, drowsiness, salivation and nausea on a scale of slight, moderate or severe, with the later four symptoms receiving greater weight.

EGGs were recorded using Fetrodes and a Fetrode bioamplifier (UFI, Morro Bay, CA) attached to a Gould polygraph. The system had an overall bandwidth of 0.008-0.3 Hz. Fetrodes for recording the EGG were attached to the subject's abdomen, one above the umbilicus in the lower one-fourth of the distance between the umbilicus and the xiphoid process, and one on the subject's left side, just below the costral margin and 8 cm left of the midline. The Fetrodes were referenced to an electrode placed on the right side of the subject's abdomen, 6 cm to the right of the subject's midline and 2 cm above the umbilicus. The EGG signal was digitized at a sampling rate of 4.267 Hz. using an IBM compatible PC and a MetraByte Dash 16 analogue to digital board and stored for later analysis. Respiration was also recorded using a strain gauge attached to the Gould polygraph in order to check visually for artifacts in the EGG.

Procedure. Subjects participated in 2 sessions: (1) motion sickness testing; and (2) persistence testing. These sessions were scheduled at least 1 day apart and were counter-balanced with every other subject starting with the motion sickness testing. For the motion sickness testing, subjects were required to come to the lab after fasting for 3 hours and abstaining from caffeine, nicotine, alcohol and drugs for at least 12 hours.

(1) Motion Sickness Testing

After subjects arrived to the laboratory, they read and signed an informed consent form. They were then prepared for electrogastrogram (EGG) and respiration recordings. After preparation, subjects were placed in an optokinetic drum in order to stimulate motion sickness. The drum period consisted of an 8 minute baseline, a 16 minute rotation, and an 8 minute recovery period. During the baseline and recovery the drum was stationary. During the entire period, subjects were asked to breath at 12 breaths per minute. Their breathing was paced with the beat of a metronome. If for any reason a subject requested early termination of rotation, the period moved directly into the recovery. Subjects were asked to rate the following symptoms while in the drum: dizziness, headache, warmth, sweating, drowsiness, salivation, gastric distress according to a scale of slight, moderate and severe, using a modified version of the Pensacola Diagnostic Index. Subjects were asked to do this before and after the baseline and before and after the recovery. After the drum period ended, the subjects were asked to complete the Nausea Questionnaire (Muth, Stern, Thayer & Koch, 1995) and a 300 mm visual-analog-scale of nausea.

(2) Persistence Testing

The persistence testing consisted of a walking task which was conducted in a long open corridor. Two strips of black tape had been applied to the white floor with a separation of 34.2 cm to define a straight 10.0 m long path. For a description of the procedure see "Walking Task" in the General Methodology section of this report.

A persistence score was defined for each subject in the following manner. The mean distance walked for the ten trials with 5 and 60 seconds occlusion times was obtained and the

persistence score was defined as the slope of the line between these means, as calculated using the following equation:

$$\frac{\text{(mean distance walked after 60 s) - (mean distance walked after 5 s)}}{55\ \text{s.}}$$

Quantification. Subjects were divided into 3 groups based on the degree of nausea and motion sickness experienced during rotation: a susceptible group; a non-susceptible group; and a non-classifiable group. The susceptible group was defined as those subjects having either:

1) a VAS score of greater than 200 mm;
2) requested early termination of rotation;
3) a VAS score of greater than 60 mm and a corrected Graybiel score (baseline reports subtracted from the reports during rotation) of greater than or equal to 6. Any subject who did not meet criteria 1 or 2 and had conflicting data on criteria 3 was placed in the non-classifiable group. The other subjects were placed in the non-susceptible group. This resulted in 22 subjects being classified as susceptible, 20 as non-susceptible and 8 were non-classifiable.

Subjects' persistence scores were correlated with their VAS scores using a rank order correlation. In addition, the persistence scores for the susceptible group were compared to those of the non-susceptible group using a between subjects t-test.

Results

As can be seen in Table 1, the group that tested susceptible to motion sickness had significantly lower persistence scores than the non-susceptible subjects, meaning that they had longer persistence as a group. This difference was significant at the 0.05 level.

When individual persistence scores were correlated with both subjective and physiological measures of nausea, the general finding was the greater the persistence, the more severe the symptoms. Two examples follow. The correlation of persistence with subject reports of nausea on a visual analog scale was 0.32, significant at the 0.05 level. And the correlation of persistence with percentage of gastric tachyrhythmia in the EGG was 0.43, significant at the 0.006 level.

EXPERIMENT II

Purpose

The two-fold purpose of Experiment II was to attempt to replicate the results of the first experiment with a new group of subjects, and to develop a new measure of visual persistence that minimized motor activity.

Method

Subjects. The subjects were 24 Penn State students, 10 males and 14 females, who had not participated in the previous experiment.

Apparatus. The same apparatus was used as in Experiment I with the addition of an IBM compatible PC which was used for the computer simulation task. The computer with attached mouse displayed a blue screen with two vertical white lines in the center of the screen. The lines were 50 pixels apart. A mouse-controlled cursor was located at the bottom of the screen between the two vertical lines. Special goggles were used to occlude the subject's vision when appropriate.

Procedure. Subjects participated in three sessions at least one day apart: motion sickness testing, the walking task, and the computer simulation task. The procedure used for the first two tasks was identical to that used in Experiment I. See the General Methodology section of this report for a description of the computer simulation task.

Results

As can be seen in Table 2, the persistence score based on the walking task for the group that was susceptible to motion sickness was more negative, meaning less persistence than the asymptomatic group, but the difference was not significant. And, again unlike the findings from the first experiment, there was not a significant positive correlation between persistence and reports of nausea and gastric tachyarrhythmia experienced in the rotating drum.

The effects of occlusion time on the computer simulation task were very different from the effects on the walking task and can be summarized as follows:

a) No systematic effect on distance travelled prior to crossing one of the two parallel boundary lines.

b) No systematic effect on standard deviation from optimal path to the end.

c) Total time to complete a trial increased from a mean of 8.0 seconds to 8.4 seconds as occlusion time increased.

Since there was not a systematic effect of occlusion time on the computer simulation task, we combined trials across occlusion times and found that there was a significant positive correlation between distance travelled prior to crossing a boundary line and reports of nausea in the rotating drum. This suggests that using this measure of persistence the results are similar to those obtained using the walking task in Experiment 1--greater persistence is associated with more severe symptoms of motion sickness.

EXPERIMENT III

Purpose

The first goal of the third experiment was to reexamine the conflicting results of the first two experiments with regard to the relationship of persistence as measured by the walking task and symptoms of motion sickness. The second goal was to look at the relationship of temporal measures of vection in relationship to symptoms of motion sickness. The third goal was to investigate the relationship of spatial abilities to susceptibility to motion sickness.

Method

Subjects. The subjects were 45 Penn State students, 30 female and 15 male, who had not participated in either of the two previous experiments.

Apparatus. The apparatus used to measure susceptibility to motion sickness and persistence as measured by the walking task were the same as that used in the first two experiments. In order to quantify the sensation of vection inside the rotating drum, the subject held a small dial, actually a voltage divider attached to a battery and one channel of the Gould recorder, and turned a knob on it from the extreme left--no vection--towards the right, indicating that he/she felt that he/she was rotating and the drum was stationary. This provided a continuous measure of the level of illusory self-motion experienced by the subject. Paper and pencil tests of spatial abilities and the rod and frame test were also added in Experiment III.

Procedure. Session 1 consisted of motion sickness testing. The only change in the procedure from the two previous experiments was that during drum rotation, the subject indicated his or her level of vection by turning a knob on a dial. Session 2 had two parts which were counterbalanced, the walking task and the spatial tasks. The procedure used for the walking task was identical to that use in the two previous experiments. Three spatial tasks were used. Subjects completed a paper and pencil mental rotation test (Shepard & Metzler, 1971), and a paper and pencil water level test (Liben, 1991) to measure their internal sense of the horizontal. In addition, the rod and frame test (Linn & Kyllonen, 1981) was used to measure the subjects' internal sense of the vertical.

Results

No systematic relationship was found between persistence as measured with the walking task and symptoms of motion sickness. The average amount of vection reported by subjects did not differ as a function of susceptibility to motion sickness. Susceptible subjects did show a significantly greater increase in percentage of gastric tachyarrhythmia from baseline to drum rotation than did the non-susceptible subjects.

For the mental rotation task, there was a significant interaction between sex of subject and susceptibility to motion sickness ($F=10.76$, $p<.002$). Of the susceptible subjects, females

did worse on the mental rotation task, but for the nonsusceptible subjects, males did worse. Subjects who developed symptoms of motion sickness did significantly worse on the water level task ($F=7.32$, $p<.01$). The results of the rod and frame test showed no systematic relationship to susceptibility to motion sickness. Males showed a significantly higher level of performance on all three tests.

GENERAL DISCUSSION

This research project was designed to be a three-year program and was funded for three years; however, funds were terminated after one year. Three experiments were completed; the focus was on developing measures of visual persistence and relating these measures to susceptibility to motion sickness. Plans had been made and permission granted to study the relationship of the persistence of visual cues to disorientation on a flight simulator at Wright-Patterson AFB, but this work could not be done because of the termination of funding.

In the first experiment, persistence as measured with a walking task was related to severity of symptoms of motion sickness. Those subjects who could walk blindfolded between two parallel lines just as well after 60 seconds of occlusion as they did after 5 seconds of occlusion, subjects who showed high persistence, reported significantly greater motion sickness than subjects who showed low persistence.

In the second experiment a computer simulation task similar to the walking task but requiring minimal motor effort was used to measure persistence. This measure when collapsed across occlusion times showed that greater persistence was correlated with greater symptoms of motion sickness. However, the walking task used in the first experiment failed to show any relationship to motion sickness.

In the third experiment we developed a continuous measure of vection, and used this as another indication of degree of persistence. However, vection was not related to reports of motion sickness, and persistence as measured with the walking task also failed to show a relationship to motion sickness. On the other hand, performance on the water level task was found to be related to susceptibility to motion sickness, but performance on the rod and frame test was not. Performance on the mental rotation task showed an interaction between sex and susceptibility to motion sickness.

The results of our initial three experiments were very promising and suggest that our concept of persistence of visual cues might be broadened to include spatial abilities. At this time we are not in a position to comment on the nature of the relationship between persistence and spatial abilities or what we might call perceptual/cognitive style. However we continue to believe that this emerging concept of perceptual/cognitive style is germane to the issue of individual differences in responding to rapidly changing visual environments. For example, the onset of disorientation problems related to the landing of a single-pilot aircraft often coincides with the moment that pilots emerge from cloud cover and make a rapid visual transition from the cockpit to the landing strip. This may well be due to visual information from the cockpit persisting and

interfering with the information being obtained from the outside environment (Leibowitz, 1987).

REFERENCES

Austin, M., Singer, G., & Day, R. H. (1969). Visual orientation illusion following judgments with a tilted visual field. Nature, 221, 583-584.

Graybiel, A., Wood, C. D., Miller, E. F., & Cramer, D. B. (1968). Diagnostic criteria for grading the severity of acute motion sickness. Aerospace Medicine, 39, 453-455.

Leibowitz, H. W. (1987). Some basic mechanisms in spatial orientation. Proceedings of Air Force Conference on Spatial Disorientation, Bolling Air Force Base.

Liben, L. S. (1991). The Piagetian water-level task: Looking beneath the surface. In R. Vasta (Ed.) Annals of Child Development, Vol. 8, p. 81-143.

Linn, M. C. & Kyllonen, P. (1981). The field dependence/independence construct: Some, one or none. Journal of Education Psychology, 73, 261-273.

Martin, L., & Li, W. (1992). Mislocalizations of visual elevation and visual vertical induced by visual pitch: The great circle model. In B. Cohen, D. Tomko, & F. Guedry (Eds.), Symposium on sensing and controlling motion: Vestibular and sensorimotor function(pp. 242-265). Annals of the New York Academy of Sciences, 656, 242-265.

Muth, E. R., Stern. R. M., Thayer, J. F., & Koch, K. L. (1995). Assessment of the multiple dimensions of nausea: The Nausea Questionnaire (NQ). Gastroenterology, 108, A654.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three dimensional objects. Science, 171, 701-703.

Stern, R. M., Hu, S., Anderson, R. B., Leibowitz, H. W., & Koch. K. L. (1990). The effects of fixation and restricted visual field on vection-induced motion sickness. Aviation, Space, and Environmental Medicine, 61, 712-715.

Stern, R. M., Koch, K. L., & Vasey, M. W. (1990). Gastrointestinal response system. In J. T. Cacioppo & L. G. Tassinary (Eds.), Principles of psychophysiology (pp. 554-579). Cambridge: Cambridge University Press.

Thomson, J. A. (1983). Is continuous visual monitoring necessary in visually guided locomotion? Journal of Experimental Psychology: Human Perception & Performance, 9, 427-443.

Tyrrell, R. A., Rudolph, K. K., Eggers, B. G., & Leibowitz, H. W. (1993). Evidence for the persistence of visual guidance information. Perception & Psychophysics, 54, 431-438.

TABLE 1

Summary of Persistence Data by Group Based on Walking Task
Used in Experiment I.

	number of subjects	mean persistence score*	standard deviation	standard error of the mean
Non-susceptible	22	-2.30	2.00	0.45
Susceptible	20	-0.94	2.25	0.48

* The greater the negative value, the less the persistence.

TABLE 2

Summary of Persistence Data by Group Based on Walking Task
Used in Experiment II.

	number of subjects	mean persistence score*	standard deviation	standard error of the mean
Non-susceptible	9	-1.21	2.33	.78
Susceptible	11	-1.81	1.92	.58

* The greater the negative value, the less the persistence.